Ortho Hydroxyazo Compounds

THESIS

presented by

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ORTHO - HYDROXYAZO - COMPOUNDS.

I. HISTORICAL SKETCH.

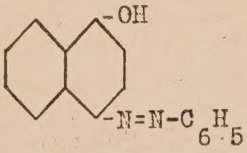
Introductory.

The constitution of the hydroxyazo-compounds has been the subject of investigation for the past thirty years. The chemical conduct of these compounds as well as their methods of preparation indicate that they are either true phenol derivatives as expressed by formula I or quinone hydrazones as expressed by formula II, and many arguments have been advanced in support of each of these formulas:

$$HO-R-N=N-R' \qquad O=R=N-NH-R'$$
$$\text{I.} \qquad\qquad \text{II.}$$

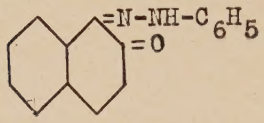
At first they were regarded as true phenol derivatives. This view was first questioned by Lieberman.[1] He pointed out that benzeneazo - β - naphthol was insoluble, or only very slightly soluble, in dilute aqueous alkalies and must therefore, possess a constitution other than that of a true phenol.

The solution of this problem was attempted first by Zincke and Bindewald.[2] They found that phenylhydrazine-hydrochloride acting upon α-napththoquinone in acetic acid solution gave a product identical with benzeneazo-α-naphthol prepared by the action of diazobenzenechloride upon α-naphthol. Since this substance is soluble in alkalies and forms ethyl and methyl oxygen ethers they assigned to it the following formula:

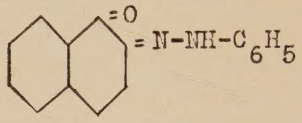


Moreover the same investigators found that when phenylhydrazine acts upon β-napththoquinone a product is formed which is

very similar to but not identical with benzeneazo-β-naphthol, prepared by the action of diazobenzenechloride upon β-naphthol. Both of these substances are almost insoluble in aqueous alkalies and both form salts with acids. The following formulas were therefore assigned to them:



"benzeneazo-β-naphthol"



"β-naphthoquinonephenylhydrazone"

Many investigations have subsequently been carried out with a view to obtaining additional evidence upon this subject. In reviewing the results of these researches the different methods of investigation will be discussed separately.

Ethers and Alkyl Derivatives.

As was mentioned above Zincke and Bindewald found that benzeneazo-β-naphthol forms an oxygen ether to which they assigned the following formula:

$$C_6H_5N = N - C_{10}H_6OR.$$

Exception to this view was taken by Meldola.[3] Five years later Jacobson[4] and his students began the investigation of this class of derivatives, studying especially the ethyl ethers. They showed that the ethyl ether of benzene-4′-azophenol by reduction gives first a hydrazo-compound.

$$C_6H_5 - N = N - C_6H_4 - O - C_2H_5 + 2H = C_6H_5 - NH - NH - C_6H_4 - OC_2H_5.$$

This substance may undergo the semidine rearrangement to give either the ortho form, C_6H_5—NH—C_6H_3 (NH_2)—OC_2H_5 (—NH—: NH_2: OC_2H_5) (6′: 4′: 1′), or the para form NH_2—C_6H_4—NH—C_6H_4—OC_2H_5 (NH_2: —NH—: OC_2H_5) (1: 4—4′: 1′) or it may undergo further reduction to give aniline and phenetidine thus:

$$C_6H_5 - NH - NH - C_6H_4 - OC_2H_5 + 2H = C_6H_5NH_2 + NH_2 - C_6H_4 - OC_2H_5.$$

The same year Witt and Schmidt[5] prepared the ethyl ether of

benzeneazo-α-naphthol but could not obtain an ethoxy-naphthylamine by its reduction.

Jacobson[6] in summing up his previous work showed that from the ethyl ethers of benzene-4′-azophenol, and each of eighteen of its derivatives studied, there is always obtained an ortho or a para semidine derivative and a partial splitting to form an ethoxy-base. Later[7] he extended this work to include benzeneazo-α-naphthol and found that by its reduction there are formed an ortho semidine, aniline and amino-α-naphthol ethyl ether. He also applied these methods to the ethers of ortho- and meta- hydroxyazo compounds[8], and found that they would undergo a similar transformation and reduction giving ethoxy-amino-compounds. Thus orthobenzeneazo phenol ethyl ether gave orthobenzenehydrazophenol ethyl ether and by further reduction aniline and orthophenetidine or a semidine-form.

Physical Methods.

Auwers and Orton[9] have attacked this problem by physical chemical methods. While making cryoscopic measurements upon a number of phenols they found that, in general, phenols exhibit an abnormally great molecular lowering, indicating dissociation. Para-benzeneazophenol and its homologues proved no exception to this rule and are therefore, apparently true phenols. The ortho-benzeneazophenols however, gave no abnormal values indicating that these compounds are either undissociated or possess some other structure than that of a true phenol derivative.

Tuck[10] has also applied physical methods to this problem, by studying the selective absorption of 10,000th molar solutions of benzeneazophenols in alcohol. By plotting the oscilation frequencies against the logarithms of the thicknesses of solution necessary to completely cut off the light, he obtained a series of extinction curves. Hartley[11] has shown that such extinction curves are similar for substances similarly constituted. Tuck found that the curves for benzene-4′-azophenol and its benzoate are very similar, while that of the parabenzoquinone-α-benzoylphenylhydrazone is distinctly different from these. The curves for benzeneazo-β-naphthol and β-naphthoquinone-phenylhydrazone are very much alike as are also those of their respective acetyl derivatives. Those of benzene-3′-azo-4′-cresol and its benzoate are very similar and in the opinion of the author are very

much like that of para benzoquinone-*a*-benzoylphenylhydrazone although the similarity is not entirely apparent.

Subststution Methods.

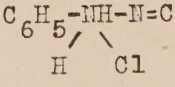
J. T. Hewitt[12] found that benzene-4′-azo-2′-nitrophenol is formed by the action of dilute nitric acid on benzene-4′-azophenol.

$C_6H_5 — N = N — C_6H_4 — OH + HNO_3 =$
$C_6H_5 — N = N — C_6H_3\ (NO_2)OH\ (N_2 : NO_2 : OH)\ (4' : 2' : 1')$

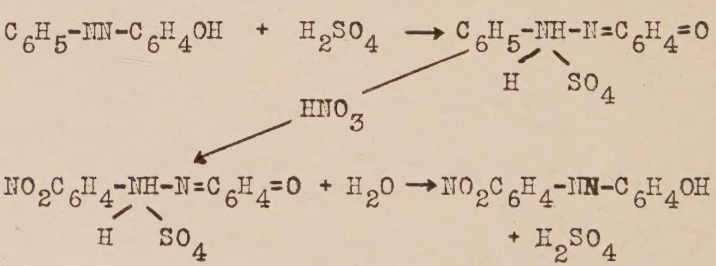
Noelting[13] previously had found that when benzene-4′-azophenol is nitrated with strong nitric acid in the presence of sulphuric acid para nitrobenzene-4′-azophenol is formed.

$C_6H_5 — N = N — C_6H_4 — OH + HNO_3 =$
$NO_2 — C_6H_4 — N = N — C_6H_4 — OH\ (NO_2 : N_2 : OH)$
$(1 : 4 — 4' : 1')$.

Hewitt explains this difference by regarding benzene-4′-azophenol as a true phenol derivative. The phenol nucleus would be expected to nitrate more easily than the benzene nucleus, hence the ortho nitrophenol derivative is obtained with dilute nitric acid. On the other hand one may regard this compound in strong sulphuric acid solution as possessing a constitution similar to that suggested by Hantzsch[14] for the hydrochlorides:



Quinone nuclei substitute with difficulty while amino derivatives do so with comparative ease. Hence in a strong mineral acid solution one would expect to get a nitrobenzene-4′-azophenol.



Hewitt and Aston[15] extending this method of investigation to the bromination of benzene-4′-azophenol found that in acetic

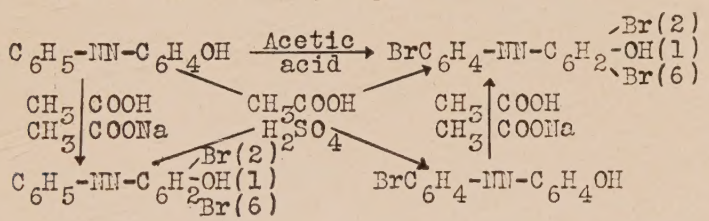
acid solution in the presence of sodium acetate benzene-4′-azo-2′, 6′-dibromophenol is formed.

$$C_6H_5 — N = N — C_6H_4 — OH + 2Br_2 =$$
$$C_6H_5 — N = N — C_6H_2Br_2OH \quad (N_2 : Br : Br : OH)$$
$$(4' : 2' : 6' : 1').$$

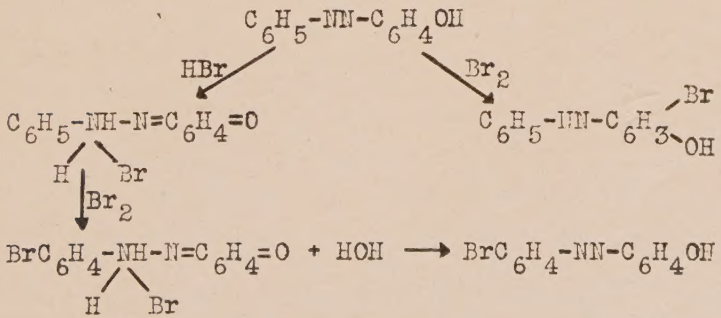
The sodium acetate serves to remove the hydrobromic acid produced in the reaction. Armstrong[16] who had brominated this compound without removing the hydrobromic acid obtained para bromo benzene-4′-azophenol.

$$C_6H_5 — N = N — C_6H_4 — OH + Br_2 =$$
$$Br — C_6H_4 — N = N — C_6H_4OH (Br : N_2 : OH) \quad (1 : 4 : — 4' : 1')$$

Hewitt and Aston[17] made a careful study of the bromination of benzene-4′-azophenol under various conditions and illustrate their results by the following diagram:—



The results are similar to those obtained in the nitration of this compound and may be explained upon the assumption that benzene-4′-azophenol in the absence of a mineral acid gives benzene-4′-azobromophenol, but the presence of a mineral acid prevents this reaction by the formation of a quinone hydrazone salt.



Hewitt and Fox[18] have similarly studied the nitration of

benzene-4′-azosalicylic acid and Hewitt and Lindefield[19] the nitration of the three toluene-4′-azophenols. In every case they found the results to be in accord with the above explanations. Hewitt and Phillips[20] in summing up the work, upon the nitration and bromination of para hydrozyazo compounds, regard them as true phenol derivatives. In strong mineral acid solutions however they take the form of the quinonehydrazone salts of Hantzsch.[14]

In applying this method of investigation to the orthohydroxyazo compounds they found, much to their surprise, that these also act toward substituting agents as true phenol derivatives. For example benzene-3′-azo-4′-cresol when brominated in the presence of sodium acetate gives benzene-3′-azo-5′-bromo-4′-cresol.

$C_6H_5 — N = N — C_6H_3(CH_3)OH =$
$(N_2 : CH_3 : OH)\ (3' : 1' : 4')$

$C_6H_5 — N = N — C_6H_2(CH_3)\ (Br)OH$
$(N_2 : CH_3 : Br : OH)\ (3' : 1' : 5' : 4')$.

Together with Auld[21], Hewitt next turned his attention to substitution in the benzeneazonaphthols. The α-naphthol derivatives gave results in accord with those of the para hydroxyazo compounds. The β-naphthol derivatives when nitrated with strong nitric acid alone gave small percentages of para nitrobenzeneazo-β-naphthol and larger percentages of 1, 6-dinitro-β-naphthol. The formation of the latter product indicates that the nitration takes place in the phenol nucleus. In the presence of strong sulphuric acid practically a quantitative yield of para nitrobenzeneazo-β-naphthol was obtained. Bromination in the absence of sodium acetate gave para bromo-benzeneazo-β-naphthol. In the presence of sodium acetate no definite compound could be isolated from the bromination product.

Hewitt and Mitchell[22] found that if they used ortho-, meta-, or para nitrobenzene-4′-azophenol the corresponding ortho, meta-, or para nitrobenzene-4′-azo-2′-nitrophenol respectively was obtained, even when the nitration was carried out in the presence of strong sulphuric acid. Further Hewitt and Walker[23] have shown that benzene-4′-azo-2′-nitrophenol and para toluene-4′-azo-2′-nitrophenol when brominated in the presence of sodium

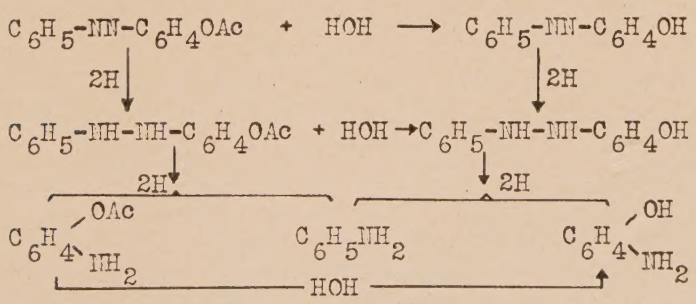
acetate yield benzene-4′-azo-2′-bromo-6′-nitrophenol and para toluene-4′-azo-2′-bromo-6′-nitro phenol respectively.

From the above considerations it is quite evident that benzene-4′-azophenol and analogous para hydroxyazo compounds in the absence of mineral acids conduct themselves toward substituting agents as true phenol derivatives. In strong acid solutions, however, they act as the quinone hydrazone salts of Hantzsch[14] would be expected to act.

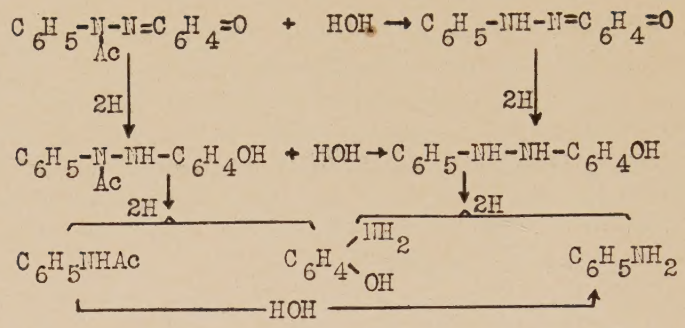
The ortho hydroxyazo compounds as represented by benzene-3′-azo-4′-cresol and benzeneazo-β-naphthol also conduct themselves in a perfectly analogous manner, under the same conditions. This is not in accord with the views of Auwers[24] who regards the free ortho hydroxyazo compounds as quinone hydrazones. It is also not in harmony with the fact shown by Jacobson and Honigsberger,[25] that meta hydroxyazo benzene forms salts with acids analogous to those formed by para and ortho hydroxyazo benzene, although according to our accepted views it cannot have a quinoid form.

Acyl-Derivatives.

The acyl derivatives of the hydroxyazo compounds like their oxygen ethers have been studied from both the stand points of synthesis and analysis. Very early the process of reductive splitting was applied to this class. If one regards the esters of hydroxyazo benzene as true phenol derivatives one would expect them to undergo reduction as follows:—



If on the other hand these compounds have the acyl group bound to nitrogen one may represent them as quinone hydrazones and their reduction in the following way.



Without discussing further the possibilities of this method of investigation, some of the results of the work along this line will be discussed.

Meldola[26] has described the reduction of the acetyl- and the benzoyl-derivatives of benzeneazo-β-naphthol with tin and hydrochloric acid. He obtained α-amino-β-naphthol and aniline together with other bases which he could not identify. In no case did he obtain acetanilide or benzanilide. He therefore regarded these derivatives as oxygen esters.

Two years later Goldschmidt and Brubacker[27] showed that the acetyl derivative of benzene-3′-azo-4′-cresol when reduced in alcoholic solution with zinc dust and acetic acid gave acetanilide and 3′-amino-4′-cresol. Using sodium amalgam and acetic acid as a reducing agent it yielded a hydrazo compound soluble in alkalies. He therefore represented the reaction by the following scheme:—

$$C_6H_5 — N(Ac) — N = C_6H_3(CH_3) = O$$
$$(— N =: CH_3 := O)\ (3' : 1' : 4') =$$
$$C_6H_5 — N(Ac) — NH — C_6H_3(CH_3)OH$$
$$(— NH —: CH_3 : OH)\ (3' : 1' : 4') =$$
$$C_6H_5NH\,Ac + NH_2C_6H_3(CH_3)OH$$
$$(NH_2 : CH_3 : OH)\ (3 : 1 : 4).$$

The benzoyl derivative by reduction in alcoholic solution with zinc dust and acetic acid gave only the alkali soluble hydrazo compound. From the acetyl and benzoyl derivatives of benzeneazo-β-naphthol under similar conditions he obtained good yields of acetanilide and benzanilide respectively and α-amino-β-naphthol.

Goldschimdt next turned his attention to the acyl derivatives of some para hydroxyazo compounds. By reduction of the acetyl and benzoyl derivatives of benzene-4′-azophenol and β-benzeneazo-α-naphthol he obtained only hydroxyazo compounds which were insoluble in alkalies. This would indicate that these derivatives should be represented as follows:—

$$C_6H_5N = N - R - Ac \quad = \quad C_6H_5 - NH - NH - R - Ac.$$

He hesitated, however, to regard them as different from the derivatives of the ortho series and considered them as nitrogen esters.

Meldola[28] objected to these views of Goldschmidt but his reasons are not clearly stated.

Goldschmidt[29] together with Pollak has offered additional evidence in support of this view. In the ortho series they submitted results on the acyl derivatives of paratoluene-3′-azo-4′ cresol, parachlorobenzene-3′-azo-4′-cresol and metachlorobenzene-3′-azo-4′-cresol and in the para series on the acetate of benzene-5′-azo-2′-cresol. All of these results were concordant with the previous ones.

Meldola, Hawkins and Burls[30] have shown the first experimental evidence at variance with the results of Goldschmidt and his students. They found that by the reduction of the acetyl derivatives of para tolueneazo-β-naphthol and ortho tolueneazo-β-naphthol, using Goldschmidts' methods, they obtained acet-α-amino-β-naphthol in small amounts in each case. Later[31] they reduced the acetyl derivative of β-naphthyleneazo-β-naphthol and obtained both β-acetonaphthalide and acet-α-amino-β-naphthol.

Before discussing further the results of the reduction methods it will be necessary to consider a kind of rearrangement peculiar to acylated amino-compounds. It has been shown by Bottscher,[32] Ransom,[33] Einhorn,[34], Auwers[35] and others, that, when those reactions, which would be expected to give oxygen esters of amino-phenols, are carried out, a nitrogen ester is always produced. Thus by the reduction of nitrophenacetin, acetaminophenol is the resulting product.

$$C_6H_4(NO_2)OAc \; = \; [C_6H_4(NH_2)OAc] \; = \; C_6H_4(NHAc)OH$$

Auwers[36] especially has studied this kind of rearrangements

and has shown that in general the following types of compounds rearrange with ease.

I. $R(NH_2)OAc = R(NHAc)OH$
II. $R(CH_2NHR')OAc = R(CH_2NAcR')OH$
III. $R(CH{=}N{-}NHR')OAc = R(CH=N-NAcR')OH$
IV. $R(NH-NHR')OAc = R(NAcNHR')OH$

At first it would seem that acids would affect this rearrangement differently from alkalies. Many of the above rearrangements however take place in acid solutions.

Willstatter and Veraguth[37] have shown that the α-acetyl-α-benzoyl- and α-carboxethyl-phenylhydrazones of para benzoquinones when dissolved in absolute ether and allowed to stand in the presence of anhydrous potassium hydroxide, rearrange to form the isomeric phenolic esters.

$$C_6H_5-NAc-N{=}C_6H_4{=}O = C_6H_5-N{=}N-C_6H_4-OAc.$$

Auwers and Eisenlohr[38] have also shown that alkalies do not accelerate this migration of the acyl group from the nitrogen to the oxygen. Further in studying Willstätter's rearrangement they have shown that alkalies do cause this migration in alcoholic solutions without or previous to saponification. A certain amount of alkali was found to be necessary, and both sodium and barium hydroxides were used. In this way one can understand how a free hydroxyazo compound may be formed by the saponification of a hydrazone.

Auwers[39] has also shown that benzene-4'-azophenol benzoate on heating with a very strong caustic soda solution reacts in two ways. A part saponifies to benzene-4'-azophenol and benzoic acid and a part splits to give benzanilide. The reaction cannot be explained by simultaneous oxidation and reduction as the molecular proportion of benzanilide is too high. Since in the presence of alkalies the acyl group migrates to the oxygen atom, the formation of benzanilide in such cases indicates that the benzoyl is originally joined to nitrogen.

Goldschmidt and Low-Beer[40] have prepared the isocyanate derivatives of benzene-4'-azophenol and studied their reduction products. The phenylisocyanate, paratolylisocyanate and ortho tolylisocyanate esters having been studied in this way.

$$C_6H_5 — N = N — C_6H_4 — OH + CO = N — R = C_6H_5 — N = N — C_6H_4 — OCO — NH — R.$$

When reduced in alcoholic solution with zinc dust and acetic acid these compounds gave alkali insoluble hydrazo compounds. The investigation was extended to the orthohydroxyazo compounds, the phenylisocyanate esters of benzene-3′-azo-4′-cresol, para toluene-3′-azo-4′-cresol and meta chlorobenzene-3′-azo-4′- cresol being studied. All reduced under the above conditions to form alkali insoluble hydrazo compounds. These hydrazo compounds on standing in alcohol solution in the presence of strong mineral acids rearranged into the benzidine forms. The benzidine derivatives when heated with sodium hydroxide split into aniline and a substance soluble in both acids and alkalies. They found that McPherson's[41] benzeneazo-β-naphthol reduces to a hydrazo compound insoluble in alkalies and which in contact with the air oxidizes rapidly reforming the hydrazone.

Auwers and Eckardt[42] have studied at length the acyl derivatives of the ortho hydroxyazo series. They found that alcoholic alkalies, piperidine and similar substances rapidly saponify benzene-3′-azo-4′-cresol benzoate in the cold. Reduction with zinc dust and acetic acid alone gave benzanilide and benzamino-4′-cresol. Reduction in alcoholic solutions with these reagents gave an alkali insoluble hydrazo compound, which by further reduction yielded small amounts of 3′-benzamino-4′-cresol and a greater proportion of benzanilide. They prepared the oxygen acetyl benzene-3′-azo-4′-cresol which had been previously described by Goldschmidt and Brubacher[27] and also by Noelting and Kohn. Complete reduction of this compound yields aniline in traces, acetanilide and 3′-acetamino-4′-cresol. The hydrazo derivative prepared according to Goldschmidt and Brubacher's method was soluble in alkalies and could be recovered unchanged by working quickly. Stronger alkalies saponify it even in alcohol solutions and oxidize the free hydrazo compound to benzene-3′-azo-4′-cresol.

Reduction of the ammonium chloride solution of the hydroazo acetate with zinc dust gave no trace of aniline and almost a quantitative yield of acetanilide and 3′-amino-4′-cresol. They, also, took up the reduction of McPherson's benzeneazo-α-naphthol benzoate and obtained benzamino-α-naphthol, traces of aniline

and no benzanilide. When the acetyl derivative was used aniline and acetanilide were obtained.

Goldschmidt and Eckhardt [43] have made the most nearly quantitative study of these reductions. They found that benzeneazo-β-naphthol benzoate yields 80-90% of benzanilide and 1.34-13.% of α-benzamino-β-naphthol. From the β-benzeneazo-α-naphthol-benzoate they obtained chiefly a hydrazo compound. In other instances 52.7-76.4% of benzanilide and 6-9% of β-benzamino-α-naphthol were among the reduction products. By reduction of the hydrazo compound, benzanilide and benzaminonaphthol were formed to the extent of 76% and 11.7% respectively.

It is at once apparent, that no definite conclusion can easily be drawn from the above results. Quinone hydrazones rearrange to form phenolic compounds when an alkali is present. Acyl groups bound to oxygen may migrate to amino groups in the ring or in the second or third position of the side chain. This migration takes place in both acid and alkaline solution, but there is no evidence to show that either accelerate the reaction. Neither has it been shown that an acyl group ever directly rearranges from oxygen to nitrogen in a quinone hydrazone. That is, Willstätter's and Veraguths'[37] rearrangement has not been reversed. Nor has it been shown that an acyl group bound to oxygen ever migrates to the second imino (NH) group of a hydrazo compound:

$$RO-C_6H_4-NH-NH-C_6H_5 = HO-C_6H_4-NH-NR-C_6H_5.$$

When such a migration takes place under these conditions the acyl group seems to attach itself to the first imino (—NH—) group:

$$HO-C_6H_4-NR-NH-C_6H_5.$$

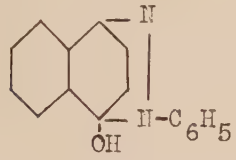
If this is true it is difficult to understand how benzanilide is formed at all, in reduction reactions except by being originally bound in this position. Further the formation of the alkali soluble hydrazo compounds, which were found by Goldschmidt and Brubacher and also by Auwers, and their extreme instability is difficult to explain, if the acyl group is bound to oxygen in the

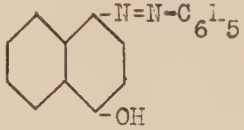
original compound. However, in these migrations which take place on reductive splitting Auwers finds a basis for believing the acyl derivatives of the ortho series are true phenol derivatives. Goldschmidt, from the results of his last mentioned paper, is as firmly convinced that they are quinone hydrazones.

Synthetic Work.

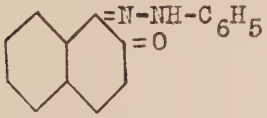
As has been mentioned above, Liebermann[1] was the first to question the constitution of hydroxyazo compounds. In studying the benzeneazonaphthols he pointed out that benzeneazo-α-naphthol is soluble in aqueous alkalies while benzeneazo-β-naphthol is insoluble or nearly so. These results caused him to doubt the presence of an hydroxyl group in the latter compound.

Zincke and Bindewald[2] studied the action of phenylhydrazine-hydrochloride upon the naphthoquinones in glacial acetic acid solutions. The product from α-naphthoquinone was found to be identical with the benzeneazo-α-naphthol of Liebermann. They proposed the two following formulas to represent its constitution:

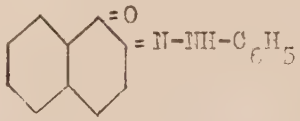




The product from β-naphtho quinone, although much like benzeneazo-β-naphthol was not identical with it. These two substances formed salts with both acids and bases. They were represented as follows:—



"benzeneazo-β-naphthol"



"β-naphtho quinone-phenylhydrazone."

Goldschmidt and Rosell[44] attempted the solution of this problem by studying the ester formation in hydroxyazo compounds. Following Zincke they pointed out that hydroxyazo benzene must have one of the two constitutional formulas:—

$HO—C_6H_4—N=N—C_6H_5$ I. $O=C_6H_4=N—NH—C_6H_5$ II.

Treating benzene-4′-azophenol with phenylisocyanate an ester was obtained which must be represented by formula III or IV.

III. IV.

$(C_7H_6NO)OC_6H_4—N=N—C_6H_5$ or $O=C_6H_4=N—N(C_7H_6NO)C_6H_5$.

The ester upon warming with alkalies split into aniline, aminophenol and carbon dioxide. This can only be explained by assuming formula III. They point out that the other ester (formula IV) is a derivative of urea and that it is difficult to explain how these products could be formed from it. Upon reduction also the ester conducts itself as an oxygen ester and not analogous to the dicarbanilido derivative of hydrazobenzene:—

$$C_6H_5—N(PhNHCO)—(PhNHCO)N—C_6H_5.$$

They were not able to condense phenyl isocyanate with any phenyl-hydrazone. Since they could not cause benzene-β-azonaphthol to condense with phenylisocyanate they regarded it as a hydrazone.

McPherson,[45] working under the direction of Nef, has shown that the condensation product of α-benzoyl-phenylhydrazine with para benzoquinone (I) is isomeric and not identical with the benzoate of benzene-4′-azophenol (II).

$O=C_6H_4=N—N(Bz)C_6H_5$ I. $BzO—C_6H_4—N=N—C_6H_5$ II.

Later[41] he extended his studies to include the acetyl- and also the benzoyl-phenylhydrazones of tolu-, thymo-, α-naphtho- and β-naphtho-quinones. He showed that all the para quinones yield hydrazones which are isomeric and not identical with the benzoates of the corresponding hydroxyazo compounds. Upon saponification both series of esters gave identical products namely free hydroxyazo derivatives. The substituted hydrazones of the (ortho) β-naphthoquinone he found to be identical with the benzoate of the free phenylhydrazone of β-naphthoquinone. Saponification under any conditions gives this same

free hydrazone. McPherson and Gore[46] extended this line of investigation studying the α-benzoyl-naphthylhydrazones of para benzo-, tolu-, and thymo-quinones. The results were completely analogous to the above. Later McPherson and Dubois[47] included monochloroquinone under this method of investigation.

Jacobson and Honigsberger[25] have prepared meta hydroxyazo benzene from meta-methoxyazobenzene by splitting the methoxy group with aluminium trichloride. The free benzene-3′-azophenol dissolves in dilute alkalies like benzene-4′-azophenol. The benzene-2′-azophenol is much less soluble. The meta derivative also forms salts under the conditions described by Hewitt and Pope[48] for the formation of salts from the ortho- and para benzeneazophenols.

Borsche[49] has shown that phenylcarbamyl hydrazine acts on para benzoquinone giving a hydrazone.

$$O = C_6H_4 = O + H_2N - NH - CO - NH - C_6H_5 = O = C_6H_4 = N - NHCONH - C_6H_5$$

He found that this substance would not condense with hydroxylamine-hydrochloride, phenylhydrazine-hydrochloride, or benzoylphenylhydrazine-hydrochloride. It does condense with carbamyl- and phenylcarbamylhydrazine salts forming:—

$$NH_2—CO—NH—N=C_6H_4=N—NH—CO—NH—C_6H_5$$

and

$$C_6H_5—NH—CO—NH—N=C_6H_4=N—NH—CO—NH—C_6H_5$$

The phenylcarbarmylhydrazone was easily benzoylated by Baumann's method:

$$HO - C_6H_4 - N = N - CO - NH - C_6H_5 = BzO - C_6H_4 - N = N - CO - NH - C_6H_5$$

This ester does not react with hydroxylamine or phenylhydrazine hydrochlorides. In the same way he studied[50] the condensation products of tolu-, thymo, α-naphtho-, and β-napthoquinones.

In a later paper[51] he has shown that formyl- and benzoyl-hydrazines act normally with para quinones. Also that benzoyl-, hippuryl-, phenylcarbamyl- and α-benzoylphenylhydrazines condense with quinonemonooximes giving quinoneoxime-hydrazones. He was not able to condense the corresponding quinone hydrazone with hydroxylamine to give the condensation products

which would be identical. In studying the action of nitrosubstituted hydrazines upon para benzo-quinone he has shown that the orthonitro- and the 2, 4-dinitro-derivatives give normal condensation products while the paranitro-derivative acts with the evolution of gas like phenylhydrazine. All condense with quinone-monooxime to give quinone-oxime-hydrazones.

Goldschmidt and Low-Beer[40] taking up again the work of Goldschmidt and Rosell[44] found the conditions under which isocyanates will unite with both para and ortho hydroxyazo compounds. Benzene-4′-azophenol reacts with phenyl-, orthotolyl-, and para tolyl-isocyanates in the cold on several hours standing. After very long standing benzene-3′-azo-4′-cresol, para toluene-3′-azo-4′-cresol and metachlorobenzene-3′-azo-4′-cresol also yielded condensation products.

$$R-N=N-C_6H_3(CH_3)OH + CONR' = R-N=N-C_6H_3(CH_3)-OCONHR'$$

Reduction of these isocyanate esters with zinc and acetic acid in alcohol solutions give hydrazo derivatives which are insoluble in alkalies. Because of this evidence Goldschmidt changed his views and concluded that all hydroxyazo compounds are true phenol derivatives.

Willstätter and Veraguth[37] as has been previously mentioned found that the oxygen esters could be formed by the rearrangement of the corresponding quinone hydrazones.

Mitchell and Smith[52] have found that diazo methane forms addition products easily with parahydroxyazo compounds and not at all with ortho derivatives. He found also as did Colombano,[53] that methylic sulphate esterified the para derivatives easily in the cold and the ortho derivatives only upon heating.

The first application of this method to the simplest ortho derivative was by McPherson and Lucas.[54] They prepared the α-benzoylphenylhydrazone of orthobenzoquinone and proved it to be identical with the benzoate of benzene-2′-azophenol of Bamberger.[55] Upon saponification the product yielded benzene-2′-azophenol or "orthohydroxyazobenzene."

Summary.

In the para series the evidence is comparatively clear. McPherson and his students have shown that two classes of esters

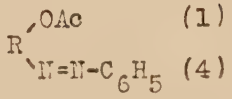
exist. The members of one class by their method of synthesis are shown to be derivatives of quinone hydrazones and are therefore nitrogen esters. Those of the other class are obtained from benzene-4′-azophenols and are oxygen esters. Both classes of esters upon saponification yield benzene-4′-azophenols. Esterification of this saponification product always reproduces the oxygen ester. This seems to indicate that the free para derivatives are true phenols, the free quinone hydrazones being unknown. Such a view is in accord with their solubility in aqueous alkalies. The rearrangement discovered by Willstätter also indicates that the phenol derivatives are the most stable form. The cryoscopic measurements of Auwers and the optical measurements of Tuck are in accord with this view, as are also the substitution experiments of Hewitt and the reduction results of both Goldschmitt and Auwers. The only contradictory fact is the one shown by Borsche that paraquinones form carbamyldihydrazones.

In the ortho series the results are not in such general agreement. Orthohydroxyazo compounds are only very slightly soluble in aqueous alkalies. That they do not esterify easily is shown by the work of Goldschmidt, Mitchell and McPherson. In order to benzoylate the phenylhydrazone of β-naphthoquinone McPherson found it necessary to carry the reaction out in alcohol solution containing one molecule of sodium ethylate. The acyl derivatives which are supposedly oxygen esters upon reduction yield acylanilides and acylaminophenols as the final products. The condensation products of substituted hydrazines with orthoquinones are identical with those obtained from the corresponding orthohydroxyazo phenols by esterification. The cryoscopic work of Auwers and the optical work of Tuck show no similarity between the free ortho compounds and phenolic substances. On the other hand Hewitt has shown, that under the same conditions, the ortho compounds act toward substituting agents in a way similar to the action of the para compounds. Further Jacobson has proven that the alkyl derivatives in both the ortho and para series are oxygen ethers.

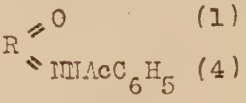
II. ORIGINAL INVESTIGATION.

Theoretical Part.

Notwithstanding the many investigations carried on with a view of determining the constitution of the hydroxyazo compounds and their derivatives, the question still remains an open one, except in the case of the acyl derivatives of the members of the para series.[41] These derivatives are prepared by the action of the acyl chlorides or the corresponding anhydrides on the parent hydroxyazo compounds. The problem to be solved in connection with their constitution resolves itself simply into one of determining whether the acyl group is joined to oxygen or to nitrogen as indicated in the two following formulas:

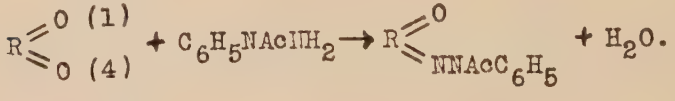


Formula I.



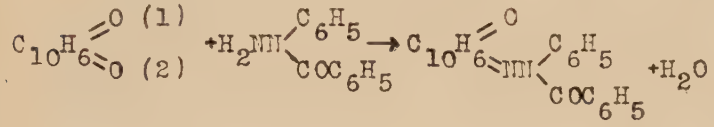
Formula II.

That formula I correctly represents the constitution of these derivatives was proven by the preparation of compounds having the constitution expressed in formula II. These compounds represented by formula II, in which the acyl group is joined to nitrogen, proved to be not identical but isomeric with the acyl derivatives of the corresponding parahydroxyazo compounds; hence in the latter compounds the acyl group must be joined to oxygen as shown in formula I above. The compounds of the type represented by formula II were prepared by the action of the unsymmetrical acylphenylhydrazines on the paraquinones as represented in the following equation:

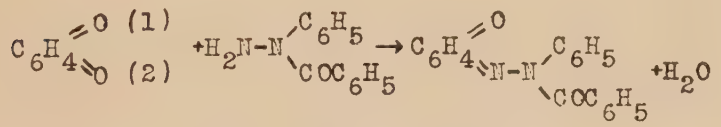


This reaction has also been extended to the orthoquinones in the hope that the question of the constitution of the orthohydroxyazo compounds might be settled in a similar way. The action of the unsymmetrical benzoylphenylhydrazine on β-naph-

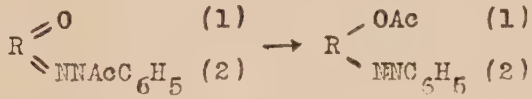
thoquinone[41] was first studied and the results were represented by the following equations:



Later the isolation of the simplest of the orthoquinones, *viz.* orthobenzoquinone[56], made it possible to study the reaction between this compound and the unsymmetrical benzoylphenylhydrazine.[54] This reaction is expressed by the following equation:

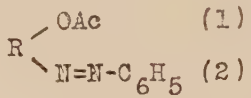


These compounds prepared by the action of the unsymmetrical benzoylphenylhydrazine on orthoquinones can also be prepared by the action of benzoyl chloride on the corresponding orthohydroxyazo compounds. Thus the compound obtained by the action of the unsymmetrical benzoylphenylhydrazine on orthobenzoquinone is identical with that obtained by the action of benzoyl chloride on orthohydroxyazobenzene. The conclusion is, therefore, inevitable that either the acyl derivatives of the orthohydroxyazo compounds have the acyl group joined to nitrogen or that in the reaction between the unsyemmetrical acylphenylhydrazines and the orthoquinones a migration of the acyl group takes place as represented by the following equation:



That such a migration takes place is made probable from the observation of Willstätter and Veraguth[37] to the effect that the acyl derivatives of the parahydroxyazo compounds undergo a similar rearrangement when heated with a small amount of potassium hydroxide in ether solution. It would seem that if the para compounds under go this rearrangement the ortho com-

pounds would undergo a similar change with still greater ease. In fact it is entirely reasonable to suppose that in the case of the ortho compounds the rearrangement might take place spontaneously. If it does not take place spontaneously, however, one would certainly expect it to take place under the same conditions which bring about the rearrangement of the para compounds. Yet these acyl derivatives of the ortho compounds undergo no change whatever under these conditions, even when heated for several hours. These facts lead to the conclusion that the acyl derivatives of the orthohydroxyazo compounds, like those of the para series, have the acyl group joined to oxygen and are therefore represented by the following formula:

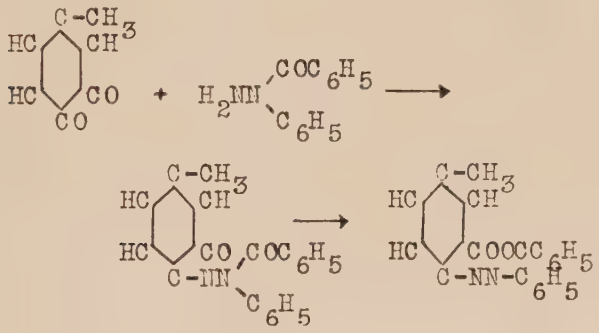


(1)
(2)

On the other hand when the benzoyl derivatives of orthohydroxyazobenzene are reduced a small percentage of benzanilide is formed as one of the reduction products. This would indicate that the benzoyl group is joined to nitrogen in the original compound; otherwise it is necessary to assume a migration of the benzoyl group from oxygen to nitrogen in the process of reduction. That such a migration is probable is shown in the investigations of Auwers and Eckhardt.[42]

The difficulty attending the preparation of orthobenzoquinone in sufficient quantities to study its condensation products in detail led to an attempt to isolate other orthoquinones of the benzene series in the hope that some of these might be more readily prepared and more stable than the orthobenzoquinone itself. It was also hoped that some information might be obtained in regard to the probable migration of the acyl group in the acyl derivatives of the orthohydroxyazo compounds. It is entirely reasonable to suppose that the ease with which such a migration takes place would be influenced by the presence of other substituents in the benzene ring and it was hoped in this way to find some orthoquinone which would react with the unsymmetrical acylphenylhydrazines to form a compound sufficiently stable to admit of its isolation, in which compound the acyl group remained joined to nitrogen. The isolation of such a compound

would definitely prove the constitution of the acyl derivatives of the orthohydroxyazo compounds. Our experiments have shown that β-orthotoluquinone ($CH_3:O:O$) (1:3:4) is not only more readily prepared than the orthobenzoquinone itself but that it is much more stable. A specimen of it left under a glass dish in the laboratory for two months showed only a slight darkening in color at the end of that period. This quinone reacts with the unsymmetrical benzoylphenylhydrazine in accordance with the following equation:



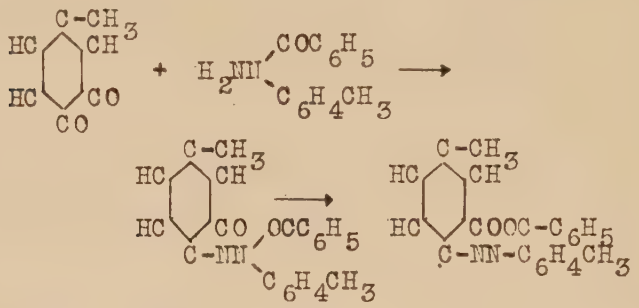
Formula I. Formula II.

That the resulting compound has the constitution expressed by formula II is shown by the following considerations. When saponified it yields benzeneazometacresol, $CH_3C_6H_3(OH)N_2C_6H_5$ ($CH_3:OH:N_2$) (1:3:4), which is isomeric with the corresponding para cresol described by Noelting and Kohn.[61] This proves that the hydrazine condenses with the oxygen which is in the para position to the methyl group in the quinone. That the acyl group is joined to oxygen rather than to nitrogen is made extremely probable from the fact that the compound undergoes no change whatever when dissolved in absolute ether, to which a small amount of fused potassium hydroxide has been added, and heated for several hours. Under these conditions the acyl group, if joined to nitrogen, should migrate to the oxygen atom as in the case of the corresponding para compounds. It is true on the other hand that when reduced with zinc dust and acetic acid, a very small percentage of benzanilide is formed; but the formation of this can be satisfactorily explained by the migration of the benzoyl group during reduction.[42] The particular interest in

the reaction between the quinone and hydrazine was centered in the efforts to isolate the possible intermediate compound in which the benzoyl group is joined to nitrogen. All attempts to prove the formation of such a compound failed.

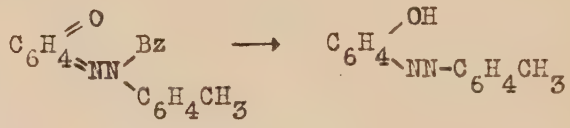
When benzeneazometacresol is benzoylated, there is formed benzeneazometacresol benzoate, identical in every respect with the product formed by the action of the unsymmetrical benzoylphenylhydrazine on the β-orthotoluquinone.

The action of the unsymmetrical benzoyltolylhydrazine on β-orthotoluquinone is similar to that of the corresponding phenylhydrazine and is represented by the following equation:



The resulting tolylazometacresol benzoate, when saponified, yields tolylazometacresol of the following constitution: C_6H_3 (CH_3) (OH) $(N_2C_6H_5)$ (1:3:4:).

As will be shown in the experimental part of this paper when orthobenzoquinone is treated with α-benzoyltolylhydrazine an ester is obtained. This benzoate upon saponification gives a paratolueneazophenol which is identical with the one described by Bamberger.[55]



In order to proceed further with the investigation it was necessary to prepare more highly substituted orthobenzoquinones. Parachloro-orthobenzoquinone[58] was prepared in absolute ether solutions from the corresponding lead salt. This quinone would not condense with α-benzoylphenylhydrazine.

In order to obtain orthoquinones either by the method of Jackson and Koch[56] or by that of Willstätter and Phannensteil[57, 58] it is first necessary to prepare the corresponding pyrocatechols. Of the homologues of pyrocatechol previously known the dibutylpyrocatechol described by Gurewitch[59] seemed the best adapted to this work. This compound was obtained by the action of tertiarybutylchloride upon pyrocatechol in the presence of anhydrous ferric chloride.

$$\underset{(OH:OH)\ (1:2)}{C_6H_4(OH)_2} + 2C_4H_9Cl = \underset{(C_4H_9:C_4H_9:OH;OH)\ (?:?:1:2)}{(C_4H_9)_2C_6H_2(OH)_2} + 2HCl.$$

The method as described by Gurewitch[59] gives a mixture of the mono and dibutylpyrocatechol which are difficult to separate. By varying the proportions, as described in the experimental part, a fairly pure mono derivative was obtained.

$$C_6H_4(OH)_2 + C_4H_9Cl = C_4H_9 - C_6H_3(OH)_2\ (C_4H_9:OH:OH)\ (?:1:2).$$

By a perfectly analogous method the monoamylpyrocatechol was also obtained. The pyrocatechols were converted into the corresponding lead salt by precipitation with lead acetate.

$$R - C_6H_3(OH)_2 + PbA_2 = R - C_6H_3O_2Pb + 2HA.$$

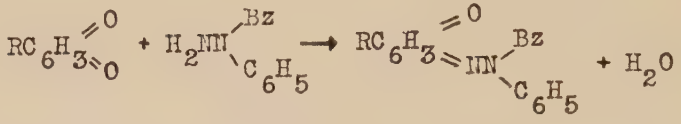
When the perfectly dry lead salt is suspended in absolute ether and treated with an ether solution of somewhat less than one molecular portion of iodine, a solution of the free quinone results.

$$R - C_6H_3O_2Pb + I_2 = R - C_6H_3(=O)_2\ (R:=O;=O)\ (?:1:2). + PbI_2.$$

Upon evaporation of the ether solutions at a low temperature in a current of air the crystalline quinones are obtained. The monobutyl and monoamyl-orthobenzoquinones resemble the free orthobenzoquinone and β-toluorthoquinone in all of their properties excepting that they are more stable.

In attempting to condense these quinones with α-benzoylphenyl hydrazine it was found necessary to use the method employed by McPherson[41] for condensing this hydrazine with β-naphthoquinone, namely by adding an alcoholic solution of the

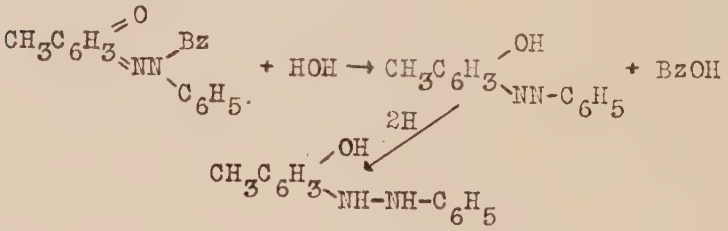
quinone to a boiling solution of the hydrazone in the same solvent.



Both quinones yield hydrazones by this method but only the monobutyl derivative was obtained as a crystalline substance the monoamyl derivative being an oil.

When saponified these hydrazones yield the corresponding hydroxyazo compounds. The monobutyl derivative is a crystalline solid while the monoamyl derivative like its parent substance is an oil. Both are almost completely insoluble in aqueous alkalies but form sodium salts in alcoholic sodium hydroxide solutions.

By reduction of the α-benzoylphenylhydrazone of β-orthotolu quinone[60] small amount of benzanilide and a product insoluble in acids are obtained. This latter substance was, at first, thought to be benzoylaminometacresol, $C_6H_3(CH_3)$ (OH) (NHC_7H_5O) (1:3:4). Analysis has shown that it is simply the free hydrazo derivative.



Experimental Part.

Preparation of β-Orthotoluquinone.—The monomethyl ester of homocatechol (kreosol) was used as the starting material in the preparation of the quinone. This ester was saponified by the action of hydriodic acid at a high temperature as described by Cousins. From 50 grams of the ester there were obtained 11 grams of pure homocatechol. From this the quinone was prepared in accordance with the general method used by Willstätter and Pfannenstiel[57] in the preparation of the orthobenzoquinone.

Two and one-half grams of the homocatechol were dissolved in anhydrous ether and to the solution were added 10.5 grams of silver oxide and 8 grams of fused sodium sulfate. The mixture was shaken for one hour and then filtered. The garnet-red ethereal solution upon evaporation deposited reddish-brown crystals of β-orthotoluquinone. Before the ether had entirely evaporated the crystals were filtered off and washed with ligroin.

The quinone was also prepared by treating the lead salt of homocatechol with iodine according to the method used by Jackson.[56] Ten grams of the homocatechol were dissolved in two liters of water and heated almost to boiling. To this hot solution was added a solution of 30 grams of lead acetate. The lead salt separated out and was washed a number of times by decantation. 5.0 grams of the dried salt were suspended in 25 cc. of chloroform and to this was added a solution of 3.9 grams of iodine in 125 cc. of chloroform. The mixture was shaken for about 15 minutes and the lead iodide removed by filtration. The resulting filtrate deposited the quinone on evaporation but the product was not so pure as that prepared by the method of Willstätter and Pfannenstiel. A purer product was obtained by substituting absolute ether for chloroform in the above method.

Analysis: Calculated for $C_7H_6O_2$: C, 68.83; H, 4.95.
Found: C, 68.72; H, 5.31.

β-Orthotoluquinone is a reddish-brown solid, non-volatile and practically odorless. It is easily soluble in acetone, chloroform, methyl alcohol, ether and benzene and is almost insoluble in ligroin. It melts at 70-75° with decomposition. From a benzene solution it separates in clusters of needles.

The Action of Unsymmetrical Benzoylphenylhydrazine on β-Orthotoluquinone. Benzeneazometacresol benzoate, C_6H_3 (CH_3) (OC_7H_5O) $(N_2C_6H_5)$ $(1:3:4)$.—The following method gave the best results: Five grams of the lead salt of homocatechol were suspended in chloroform and iodine added as described for the preparation of the quinone. The lead iodide was removed by filtration and the resulting filtrate added directly to a solution of 3.2 grams of unsymmetrical benzoylphenylhydrazine in chloroform. The resulting mixture at once turned dark and upon spontaneous evaporation deposited an oily tar. This tar was repeatedly extracted with petroleum ether and the combined

extracts upon evaporation deposited tufts of yellow needles together with a reddish oil. The mass was stirred with cold methyl alcohol, which dissolved out the oil. The remaining crystals were further purified by crystallization from ligroin. In this way 2 grams of orange-yellow needles melting sharply at 98° were obtained.

Analysis: Calculated for $C_{20}H_{16}N_2O_2$: C, 75.91; H, 5.10.
Found: C, 75.69; H, 5.23.

Benzeneazometacresol benzoate is an orange-yellow solid, very slightly soluble in cold methyl and ethyl alcohol but readily so in hot ligroin and benzene.

The Reduction of Benzeneazometacresol Benzoate.—3.94 grams of the benzoate were dissolved in about 50 cc. of glacial acetic acid. Small portions of zinc dust were added from time to time and the mixture warmed. In a few minutes the solution became almost colorless. It was decanted from the zinc and poured into water (750 cc.). On stirring there soon separated a slightly pinkish solid. This was filtered off and treated with a very dilute solution of sodium hydroxide. There remained a residue of 0.15 gram which proved to be benzanilide. Upon acidifying the alkaline solution a white flocculent precipitate (1.11 grams) was formed, which when purified melted at 159-160°.

Analysis has shown this compound to be the free hydrazo derivative:

$$C_6H_3(CH_3)\ (OH)\ (NH-NH-C_6H_5)\ (1:3:4:).$$

Analysis: Calculated for $C_{13}H_{14}N_2O$: C, 72.90; H, 6.54.
Found: C, 72.79; H, 6.31.

Saponification of Benzeneazometacresol Benzoate:—Benzeneazometacresol, $C_6H_3(CH_3)\ (OH)\ (N_2C_6H_5)\ (1:3:4)$.—The benzoate was saponified by dissolving in cold concentrated sulfuric acid and pouring the resulting solution into water. Benzeneazometacresol separated out and was purified by crystallizing from hot ligroin.

Analysis: Calculated for $C_{13}H_{12}N_2O$: C, 73.58; H, 5.66.
Found: C, 72.97; H, 5.80.

Benzeneazometacresol ($CH_3 : N_2$) (1 : 4) crystallizes from hot ligroin in thin red plates melting at 122°. It is readily soluble in alcohol, benzene, acetone and chloroform. Like the other known orthohydroxyazo compounds it is very slightly soluble in alkalies. It was benzoylated by dissolving in absolute alcohol containing the theoretical amounts of sodium ethylate necessary to form the sodium salt and then adding a slight excess of benzoyl chloride. The resulting benzoate was purified by crystallization, first from methyl alcohol and finally from ligroin. It proved to be identical with the original benzoate prepared by the action of the unsymmetrical benzoylphenylhydrazine on β-orthotoluquinone.

The Action of Unsymmetrical: — *Benzoyltolylhydrazine on β-Orthotoluquinone*: — *Tolylazometacresol Benzoate,* C_6H_3 (CH_3) (OC_7H_5O) $(N_2C_6H_4CH_3)$ (1 : 3 : 4)—This reaction with the tolylhydrazine was carried out under the same condition as with the phenylhydrazine described above. There was thus obtained an orange colored solid melting at 93°.

Analysis: Calculated for $C_{21}H_{18}N_2O_2$: C, 76.36; H, 5.45.
Found: C, 75.71; H, 5.64.

Tolylazometacresol benzoate is slightly soluble in cold methyl and ethyl alcohol and readily so in hot benzene and ligroin. It is deposited from ligroin in the form of light orange colored needles. When dissolved in sulfuric acid and the resulting solution poured into water tolylazometacresol, $C_6H_3(CH_3)$ (OH) $(N_2C_6H_4CH_3)$ (1 : 3 : 4), was deposited as an organe-red solid which on which on crystallization from ligroin melted at 148°.

Analysis: Calculated for $C_{14}H_{14}N_2O$: C, 74.33; H, 6.19.
Found: C, 74.24; H, 6.13.

Tolylazometacresol readily dissolves in hot ligroin, crystallizing out in the form of thin lath-shaped crystals, orange-red in color. Like the other orthohydroxyazo compounds it is very slightly soluble in alkalies. It is isomeric with the paratolylazoparacresol, $C_6H_3(CH_3)$ $(N_2C_6H_4CH_3)$ (OH) (1 : 3 : 4), described by Noelting and Kohn.[61] When benzoylated by dissolving in alcohol containing sodium ethylate and adding benzoyl chloride, tolyl-

azometacresol benzoate is formed, identical with the compound formed by the action of the unsymmetrical benzoyltolylhydrazine on β-orthotoluquinone.

Action of Unsymmetrical benzoyl paratolylhydrazine upon orthobenzoquinone; paratoluene-2′-azophenol benzoate. C_6H_4 (OC_7H_5O) $(N_2C_6H_4—CH_3)$ (1 : 2).

Five grams of the lead salt of pyrocatechol were suspended in 25c.c. of chloroform and a solution of 3 grams of iodine in 125c.c. of chloroform added. After shaking the mixture for 15 to 20 minutes the resulting solution was filtered into a solution of 3 grams of α-benzoyl-paratolylhydrazine in chloroform. The mixture was well shaken and allowed to evaporate spontaneously. A tarry mass was deposited which was extracted several times with ligroin. The resulting solutions upon evaporation deposited nodules of yellow needles and a crystalline shell upon the bottom and sides of the beaker. The crystals were removed and purified by repeatedly crystallizing out of hot methyl alcohol in which the substance is only slightly soluble, while the tarry impurity is quite soluble. After twice recrystallizing from ligroin the product was obtained in mats of fine silky orange colored needles melting at 85 to 86°C.

Analysis: Calculated for $C_{20}H_{16}O_2N_2$: C, 75.95; H, 5.65.
Found: C, 76.18; H, 5.57.

Paratoluene-2′-azophenol benzoate is only very slightly soluble in cold ethyl and methyl alcohols but readily soluble in benzene, chloroform and hot ligroin. It is only slightly soluble in cold ligroin.

For the preparation of these benzoates in quantities it was found to be advisable to use anhydrous ether as the solvent in place of chloroform. It has the advantage of evaporating more quickly and at a lower temperature. While the yield is no greater the work is greatly facilitated.

Saponification of paratoluene-2′-azophenol benzoate; paratoluene-2′-azophenol. $C_6H_4(OH)$ $(CH_3)N_2C_6H_4CH_3)$ (1 : 2).

The benzoate was saponified by dissolving in cold concentrated sulphuric acid and pouring the resulting solution into water. Paratoluene-2′-azophenol seperated out and was purified by crystallizing from ligroin. This substance proved to be iden-

tical with the paratoluene-2′-azophenol obtained by Bamberger[55] by the action of orthonitrosophenol upon paratoluenediazonium chloride. Each of these substances as well as a mixture of the two melt at 100°C.

Preparation of mono-tertiary-butylpyrocatechol. C_4H_9—$C_6H_3(OH)_2$.

A Gurewitch[59], working under the direction of Prof. Nencki, has described a ditertiarybutylpyrocatechol. He obtained this substance by dissolving 11 grams of pyrocatechol in 18 grams of the tertiary butylchloride. After cooling 2.5 grams of anhydrous ferric chloride were added and the mixture warmed on the water bath. The reaction was complete in about six minutes. The product was purified by dissolving it in alcohol and digesting with animal charcoal. The mixture was then filtered and water added to the filtrate. Needle like crystals were deposited. Recrystallized from benzene the substance formed yellow crystals melting at 85° to 86°C.

Upon attempting to repeat this preparation it was found that 11 grams of pyrocatechol are not soluble in 18 grams of the tertiary butylchloride even when boiled under a reflux condensor for an hour. A pasty mass was formed. This was cooled and 2.5 grams of sublimed ferric chloride added. The reaction started at once. By warming on the water bath under a reflux condensor a violent evolution of hydrochloric acid took place. In 6 or 7 minutes the reaction subsided. The substance could not be purified by the method of Gurewitch. The product formed would not crystallize and upon further dilution a dark heavy oil separated. This oil was repeatedly washed with water to remove any unchanged pyrocatechol, and finally taken up in ether. The ether was separated from the remaining water and transferred to a 250c.c. distilling flask. The ether was removed by distillation and the substance distilled in vacuo. With due care the last traces of moisture can be removed by careful heating. The distillate was collected in three fractions the second boiling almost constant at 182.5C. under 30 m. m. pressure. The first and third were redistilled and the constant boiling portion added to the previous one. The combined constant boiling portions were then redistilled. Thirty-three grams of pyrocatechol yielded 35 grams of the constant boiling product. The freshly distilled product is a thick, viscous,

transparent, slightly yellow oil. After standing for two days in a cool place crystallization started, and by stirring with a glass rod proceeded rapidly with evolution of heat. The powdered mass melted at 63°C. When taken up in its own volume of a mixture of benzene-ligroin and then cooled in a freezing mixture it recrystallizes in white hair like needles melting at 65°C. By taking the viscous oil up in alcohol and adding water, in small portions, a crystalline product could not be obtained, the substance always being precipitated as an oil. Repeated recrystallization from benzene-ligroin does not raise the melting point.

Analysis: Calculated for $C_{10}H_{14}O_2$: C, 72.29; H, 8.43.
Found: C, 72.89; H, 9.13.
Calculated for $C_{14}H_{22}O_2$: C, 75.67; H, 9.91.

It is evident from the analysis that the substance is a mixture of the mono and dibutylpyrocatechol, consisting mostly of the mono derivative. By using only a single molecular portion of the tertiary chloride the results were not good. With about 1½ molecules of the tertiary chloride a larger percentage of the mono derivative was obtained but it was not possible to entirely free it from traces of the disubstituted derivative. It was used in this condition for the preparation of the following lead salt.

Lead Salt of the Mono Tertiary Butylpyrocatechol. C_4H_9-$C_6H_3O_2Pb$. — 13.65 grams of the crude monobutylpyrocatechol were dissolved in 100cc of ordinary alcohol and this solution added drop by drop to a cold solution of an excess of lead acetate (2 mols.) in 500c.c. of water. During the addition the lead acetate solution was vigorously stirred by a mechanical stirring device. The lead salt of the pyrocatechol began to separate at once as a cream colored solid. After all the pyrocatechol solution had been added the mass was diluted to 1000 c.c. and the stirring continued for 5 or 10 minutes. The precipitated lead salt after settling was washed 8 or 10 times by decantation. It was then filtered by suction and dried first on a porous plate, and finally on the steam plate. Yield about 22 grams of a bright green, amorphous salt. Theory 25.6 grams.

Preparation of Monobutyl-orthobenzoquinone: C_4H_9—C_6H_3 (O:O) (1:2).

Five grams of the lead salt were suspended in 75 cc. of absolute ether and 2.5 grams of iodine, in just enough anhydrous

ether to dissolve it, added. The mixture was shaken vigorously for about 15 minutes, allowed to settle and filtered. The solution is bright red in color with a greenish fluorescence. The filtrate was collected in a 300 cc. Erlemeyer flask and evaporated by aspirating a current of air over it while standing in a freezing mixture. When concentrated to about $\frac{1}{4}$ its original volume the solution began to deposit reddish yellow crystals. Before complete dryness was reached the mass was filtered by suction and washed repeatedly with ligroin. The collected washings and mother liquor when concentrated under the same conditions deposited a second crop of crystals. After a single recrystallization from ligroin the substance forms bright red lath shaped needles melting at 63°C. Yield from the first recrystallization 1.5 grams.

Analysis: Calculated for $C_{10}H_{12}O_2$: C, 73.17; H, 7.31.
Found: C, 72.85; H, 7.53.

Mono tertiary butyl-orthobenzoquinone resembles very closely the ortho benzoquinone and the β-tolu-orthoquinone. It is readily soluble in alcohol, benzene and ether, slightly soluble in ligroin.

Five-tenths of a gram of the above quinone were dissolved in 6 c.c. of glacial acetic acid and a solution of 0.4 of a gram of phenylhydrazine hydrochloride in water added. A very slight evolution of gas took place and the solution soon became turbid but no condensation product could be isolated.

Action of Unsymmetrical benzoylphenylhydrazine upon Monobutyl - orthobenzoquinone; Benzene-2' - azomonobutylphenol benzoate. $C_4H_9—C_6H_3$ (OC_7H_5O) $(N_2C_6H_5)$ (1:2).

By using the conditions described above, for the preparation of orthoquinone hydrazones the butyl-orthobenzoquinone cannot be condensed with the uns.-benzoylphenylhydrazine. 1 gram of the above quinone was dissolved in 30 c.c. ordinary alcohol; this solution was added to a boiling solution of 2 grams of the hydrazine sulphate in 180 c.c. of 20% alcohol through the condensor. The bright red color of the quinone vanished immediately upon contact with the hydrazine solution and the mixture at once becomes turbid with an orange colored precipitate. After 1 to 2 minutes boiling the heating was stopped and the mixture poured into water. An oil began to separate at once and soon collected

in a pasty mass. This was removed by filtering and dried on a porous plate over night when it still retained its pasty consistency. The paste was then taken up in cold methyl alcohol and the solution cooled in a freezing mixture. Upon rubbing the sides of the beaker with a glass rod crystallization started in small yellow nodules. Recrystallized twice from ligroin the substance melted at 120°C.

Analysis: Calculated for $C_{23}H_{22}N_2O_2$: C, 77.10; H, 6.15.
Found: C, 77.12; H, 6.52.

Benezene-2′-azomonobutylphenol benzoate forms orange yellow prisms easily soluble in benzene slightly soluble in hot ligroin and hot methyl and ethyl alcohols. Almost insoluble in cold acohols.

Saponification of Benzene-2′-azomonobutylphenol benzoate; Benzene-2′-azomonobutylphenol. C_4H_9—C_6H_3 (OH) ($N_2C_6H_5$) (1 : 2).

Five-tenths grams of the above hydrazone were dissolved in hot methyl alcohol, an excess of strong sodium hydroxide added and the mixture heated for an hour. The solution was allowed to evaporate spontaneously. A bright red sodium salt of the free phenol and sodium benzoate were deposited. The mixture was dissolved in water and acidified with dilute hydrochloric acid. The light reddish yellow oil which separated solidified and was twice recrystallized from ligroin. It forms light yellow leaves.

Preparation of Mono tertiary amyl pyrocatechol. C_5H_{11}—C_6H_3 $(OH)_2$.

The tertiary amyl chloride was found to react with pyrocatechol even more readly than the butyl chloride. 23 grams (2 mols.) of the tertiary amyl chloride were heated under a reflux condensor with 11 grams of pyrocatechol. A pasty mass was formed. The reaction started even before the addition of ferric chloride. After the addition of 2.5 grams of the sublimed ferric chloride the violent evolution of hydrochloric acid is ended in about 6 to 7 minutes. The reaction mixture was purified as in the case of the butyl derivative. These proportions yield a mixture of the mono and diamyl substitution product. By taking a less proportion of the tertiary chloride an almost pure mono derivative is obtained; 22 grams of the pyrocatechol were heated with 30 grams of the chloride in the presence of 5 grams

of the ferric chloride. The condensation product fractionated almost completely at 182° to 183°C. under 18 m.m. pressure. The substance closely resembles the monobutyl pyrocatechol being a heavy, slightly yellow, viscous, transparent oil. Yield after three distillations 26.5 grams. The boiling point remains constant to within one degree during the distillation.

Boiling point under 18 m.m. ..... 182 to 183°C.
" " " 16 m.m. ..... 180°C.
" " " 12 m.m. ..... 173 to 174°C.

Upon cooling and seeding or by rubbing the sides of the Brill tube with a glass rod the viscous oil solidifies to a mass of fine hair like crystals. When taken up in its own volume of ligroin and cooled, it again separates in hair like crystals which when dried melt at 50° to 55°C.

Analysis: Calculated for $C_{11}H_{16}O_2$: C, 73.33; H, 8.88.
Found: C, 74.19; H, 9.08.
Calculated for $C_{16}H_{26}O_2$: C, 76.80; H, 10.40.

The substance was very evidently contaminated with diamyl derivative but was used in this condition for the preparation of the following lead salt.

Monoamylpyrocatechol Lead salt: $C_5H_{11}—C_6H_3O_2Pb$..

Thirty-one grams of the monoamylpyrocatechol in two portions were dissolved in alcohol and converted into the lead salt by adding slowly to a solution of 2 molecules of lead acetate as in the case of the butyl derivative. The precipitated salt was washed by decantation filtered by suction and dried on the steam plate. Yield 44.5 grams of an amorphous yellowish-green salt.

Monoamyl-orthobenzoquinone: $C_5H_{11}—C_6H_3O_2$.

Five grams of the above lead salt were suspended in 75 c.c. of anhydrous ether. To this was added a solution of 2.5 grams (less than 1 mol.) of iodine in the same solvent and the mixture shaken for 10 to 15 minutes. After settling the reddish yellow solution was filtered and evaporated as in the case of the butylquinone. Yield .85 grams of bright red crystals resembling the butyl derivative in all respects. Melts sharply at 50.5°C.

Analysis: Calculated for $C_{11}H_{14}O_2$: C, 74.16; H, 7.86.
Found: C, 74.01; H, 7.92.

Action of Unsymmetrical benzoylphenylhydrazine upon Monoamyl orthobenzoquinone; Benzene - 2′ - azomonoamylphenol: $C_5H_{11}—C_6H_3$ (OC_7H_5O) $(N_2C_6H_5)$ (1:2).

In order to condense this monoamyl-orthobenzoquinone with the above mentioned hydrazine the reaction was carried out in a manner perfectly analogous to that used in the condensation of the butylquinone with this substance. I have not yet been able to crystallize the orange-yellow oil obtained. When saponified under the conditions given for the butylhydrazone a bright red sodium salt is formed but the free derivative like its ester proved to be an oil.

Summary.

Three new orthoquinones have been described. The simplest of these β-orthotoluquinone condenses with substituted hydrazones like orthobenzoquinone. The saponification products of these hydrazones are only slightly soluble in aqueous alkalies and the method used for β-naphthoquinone must be used to benzoylate them. These benzoates are identical with the original esters respectively. The other two quinones, monobutyl and monoamylorthobenzoquinones condense with substituted hydrazones only when the condensation is carried on by the method used for β-naphthoquinone They decompose only feebly with phenylhydrazine. The position of the tertiary alkyl groups in the benzene ring has not been determined and no method has yet been found for settling this question. The work will be continued and it is hoped that a solution of this difficulty will be found.

No decisive evidence has been found as to the constitution of orthohydroxyazo compounds, but progress has been made toward closing up the gap between "orthohydroxyazobenzene" and "β-naphthoquinonephenylhydrazone." The way has been opened for completing the study of this question by the synthetic method.

In conclusion, I wish to express my deep sense of gratitude to Prof. Wm. McPherson, under whose supervision this research has been carried on, for the interest he has shown and for his very helpful suggestions and advice at all times.

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Ortho Hydroxyazo Compounds

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